A Housing Energy Management Program Report

Energy
Ontario

CONDENSING OIL FURNACE
FIELD TEST
"INSTALLATION REPORT"
REPORT No. 11A

Funding was provided equally by the Ministry of Municipal Affairs and Housing through funds provided by the Ministry of Energy, through the Housing Energy Management Program (H.E.M.P.), Esso Petroleum Canada and Eneroil Research Limited.

Prepared for
Ontario Ministry of Municipal Affairs and Housing
Housing Renovation and Energy Conservation Unit

by

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March 1.

ISBN No. 0-7743-9..2-4

ABSTRACT

The Condensing Oil Furnace Field Test: "Installation Report" describes study objectives, testing procedures and installation details for a field test of a high efficiency condensing oil furnace which has recently been developed for the domestic market.

The field test is designed to generate data on the seasonal operating efficiency of the furnace. In addition, the test will provide an opportunity to assess the effects of extended use on furnace parts and operating characteristics, and to document service and maintenance requirements.

The installation and instrumentation of the condensing oil furnace for test purposes has been completed. Field test results will be presented in a forthcoming "Performance Report".

The condensing oil furnace field test involves participation from both industry and government. The test results will be used to further product development and to contribute to the current body of public information on energy efficient heating equipment.

CONTENTS

		PAGE
1.0	INTRODUCTION	1
2.0	OBJECTIVES	2
3.0	THE CONDENSING OIL FURNACE	3
4.0	FIELD TEST PROCEDURES	6
5.0	INSTALLATION OF TEST EQUIPMENT	9
	5.1 Test Site	9
	5.2 Installation Details	9
	5.3 Start-Up Testing and Preliminary Trials	12
6.0	CONCLUSIONS	17

1.0 INTRODUCTION

A condensing oil furnace is an oil-fired forced air furnace, in which flue gases are cooled and condensed to extract additional heat. The result is a system that should be more energy efficient than a conventional system, which has no mechanism for recovering heat from flue gases.

A new condensing oil furnace has recently been developed for domestic use. This high-efficiency heating system is currently being refined for introduction into the residential market in the near future. This condensing furnace has not yet been approved in Canada, although it is presently being evaluated by the Canadian Standards Association (CSA).

Field testing of the condensing oil furnace is extremely important. Extended field testing will generate valuable information regarding installation techniques, efficiency, reliability and servicing requirements.

In recognition of the importance of field testing, a consortium involving the Ministry of Municipal Affairs and Housing, Esso and Eneroil, with consulting services provided by Enerplan, was assembled to monitor and analyze the performance characteristics of the condensing oil furnace under extended field conditions.

The test results will be used by the designer, manufacturer and distributor in refining the furnace for successful introduction into the residential market. In addition, test data will be made available to other interested groups and individuals.

The "Installation Report" presents field test objectives, outlines testing procedures, and describes installation details. Field test results will be presented in a forthcoming "Performance Report".

2.0 OBJECTIVES

The objectives of the field test of the condensing oil furnace are:

1. **to estimate the seasonal operating efficiency of the condensing oil furnace**

   Seasonal efficiency will provide a useful indicator of long term field performance in the test case.

2. **to measure seasonal energy losses attributable to various functions of the condensing oil furnace (ie. flue gas exhaust, condensate drainage, etc.)**

   Measurements of specific energy losses on a seasonal basis will assist in understanding why certain efficiency levels are achieved and how they can be maintained or improved.

3. **to assess the effects of extended field use on furnace parts and operating characteristics**

   Detailed equipment inspections will reveal any signs of wear, corrosion, mechanical failure, build-up of deposits, etc.

4. **to document installation, service and maintenance requirements**

   A detailed record of installation, service and maintenance requirements will provide useful information for improving equipment design, training service representatives, developing service manuals, improving ease of installation, reducing maintenance requirements, etc.

3.0 THE CONDENSING OIL FURNACE

The condensing oil furnace which was selected for the field test is essentially a conventional oil furnace with the following fundamental modifications (see Figure 1).

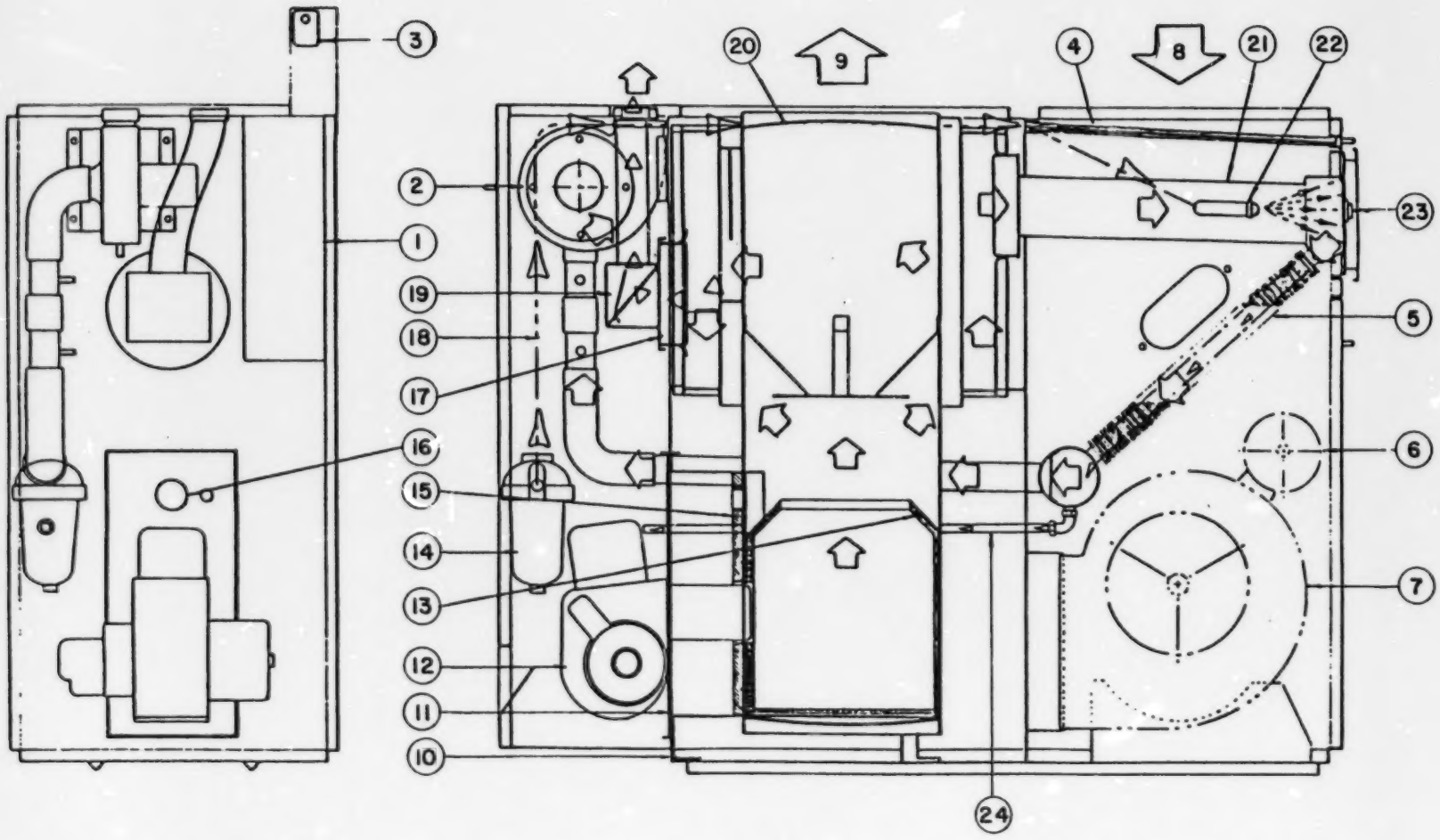
- a second, stainless steel heat exchanger is located in the path of the return air plenum
- flue gases flowing through the second heat exchanger are cooled to the point where water vapour condenses to liquid water, and releases latent heat
- water is injected into the path of the flue gases before passing through the second heat exchanger. This water is heated to steam and adds latent heat to the flue gases. The water also removes particulates from the flue gases and dilutes the flue gas condensate.
- a draft induction fan forces flue gases out of the furnace through a 50mm (2") diameter ABS plastic pipe. A draft proving, pressure sensing device insures proper exhaust of flue gases while the burner is operating.
- the temperature of flue gases leaving the furnace after the condensing process is approximately 38^{o}C (100^{o}F).

The condensing oil furnace is fired by a high efficiency flame retention head burner. Fuel nozzle size options range from 0.5 to 0.75 USgph.

Steady state efficiencies of 94% and higher have been demonstrated in previous laboratory and field tests. Seasonal operating efficiencies are expected to be close to these levels since off cycle losses are virtually eliminated due to low stack temperatures and induced draft.

The unit will carry a retail price tag of $1,800.00 to $2,000.00 (plus installation costs) and is designed to meet current needs for high efficiency equipment in the replacement oil furnace market, particularly in areas where natural gas service is not available.

Figure 1



HIGH EFFICIENCY OIL CONDENSING FURNACE

Figure 1 (con't)

HIGH EFFICIENCY CONDENSING OIL FURNACE

LEGEND

1	JUNCTION BOX
2	INDUCED DRAFT BLOWER
3	FAN LIMIT CONTROL
4	PERMANENT AIR FILTER
5	TRANSFER FIN TUBES
6	BLOWER MOTOR
7	BLOWER
8	COLD AIR RETURN
9	WARM AIR RETURN
10	POUCH OPENING
11	POUCH PLATE
12	OIL BURNER
13	MINERAL FIBRE COMBUSTION CHAMBER
14	WATER FILTER
15	MINERAL FIBRE POUCH OPENING SEAL
16	VIEWPORT
17	CLEAN OUT
18	WATER LINE
19	BY-PASS VALVE
20	HOT ROLLED STEEL HEAT EXCHANGER ASSEMBLY
21	STAINLESS STEEL SMOKE PIPE
22	STAINLESS STEEL WATER ATOMIZER
23	WATER SENSOR
24	CONDENSATE DRAIN PIPE

⌂ AIR FLOW

△ BY-PASS AIR FLOW

▷ CONDENSATE / WATER FLOW

4.0 FIELD TEST PROCEDURES

The field test is designed so that the condensing oil furnace is operated throughout as much of the 1983-84 heating season as possible. Instrumentation and data collection strategies focus on the performance characteristics of the condensing oil furnace.

As an added dimension to the test an electric plenum heater will be used to provide a base of data against which the condensing oil furnace performance data can be compared. The plenum heater will be operated for brief periods throughout the 1983-84 heating season to provide an indication of the actual energy load of the test house (ie. assuming electricity is 100% efficient).

The monitoring instruments, data to be collected, and recording methods are presented in Figure 2. A data logging sheet is shown in Figure 3.

In addition to ongoing monitoring, detailed inspections of the condensing oil furnace will be conducted at the beginning of the monitoring period and at the end of the 1983-84 heating season. These inspections will include:

- measurement of actual oil flow rate
- measurement of condensate flow rate
- measurement of condensate temperature relative to service water temperature
- flue gas analysis
- measurement of over-fire draft
- burner adjustment if necessary
- inspection of the furnace to identify signs of wear, corrosion, soot build up, deposits, etc.

It is noteworthy that the installation (see Section 5.0) is designed so that the original oil furnace is left in place. The test site is therefore very flexible. In addition to continued monitoring of the condensing oil furnace and electrical plenum heater, it will be possible in future heating seasons to log additional comparative data on the original furnace, in its current or retrofitted form.

Figure 2

INSTRUMENTATION AND DATA COLLECTION

INSTRUMENT	DATA TO BE COLLECTED	METHOD
1. multi point strip chart recorder	a) outdoor ambient temperature b) indoor space temperature (main floor living area) c) basement ambient temperature d) vestibule temperature e) stack temperature (condensing oil furnace) f) return air temperature (condensing oil furnace) g) supply air temperature (condensing oil furnace) h) temperature at fan coil unit after secondary heat exchanger (condensing oil furnace)	all temperature data to be recorded automatically and continuously by chart recorder; charts to be replaced by technician at 3 - 4 week intervals
2. oil flow meter	condensing oil furnace fuel consumption (litres)	meter readings to be recorded daily by homeowner
3. elapsed timer	burner elapsed "ON" time (condensing oil furnace)	timer readings to be recorded daily by homeowner
4. event counter	burner firing frequency (condensing oil furnace)	counter readings to be recorded daily by homeowner
5. event counter	plenum heater cycle frequency	counter readings to be recorded daily by homeowner
6. electricity use (kWh) meter	plenum heater energy consumption (kWh)	meter readings to be recorded daily by homeowner

DATA RECORDING SHEET

SHEET NO. ___

READING NO.	DATE (YR/MO/DAY)	TIME (HRS:MIN)	MAIN ELECTRICITY METER (kWh)	SUB ELECTRICITY METER (kWh)	OIL BURNER FREQUENCY	OIL BURNER "ON" TIME	PLENUM HEATER FREQUENCY	OIL FLOW (DM)	OIL TANK (FLOAT GAUGE LEVEL)	NOTES

5.0 INSTALLATION OF TEST EQUIPMENT

5.1 Test Site

The site for the condensing oil furnace field test is a single detached house located in North York, Ontario. (See Figure 4.) The house is a brick veneer, split-level model built in 1959. The heated floor area, which includes part of the basement, is approximately 204m^2 (2197 sq.ft.).

A HOTCAN computer analysis was performed on the test house in order to simulate current heat loss characteristics. The HOTCAN model predicted a design heat load of 16.15 kW (55104 Btuh) and an annual space heating consumption of 4556 litres of fuel oil ($1517.27 @ $0.333/litre).

The complete HOTCAN computer printout, including a listing of building component areas and RSI-values, as well as estimates of design and annual heat loads, is presented in Appendix A.

The test house uses fuel oil for space heating and electricity for domestic water heating, lights and appliances. Fuel oil consumption records were available from 1975. The average annual fuel oil consumption from calender 1975 to calender 1982 (inclusive) was 3551.8 litres (780.6 gallons). With the exception of the addition of a small amount of attic insulation (approximately RSI 2/R11), the building envelope was not modified in any way during this period. The original oil furnace remains as installed when the house was built, although the fan limit switch has been adjusted in recent years to extend the fan cycle.

5.2 Installation Details

The installation of the test heating equipment is designed to enable the following basic operating modes:

- the condensing oil furnace operated independently
- the original oil furnace operated independently
- the electric plenum heater operated independently
- the electric plenum heater operated with the condensing oil furnace as a back-up system
- the electric plenum heater operated with the original oil furnace as a back-up system

In order to enable the above operating modes, the installation has been completed as follows:

Fig. 4 - Field Test Site

1. the condensing oil furnace and the original oil furnace are installed side-by-side (see Figure 5)

2. the electric plenum heater is installed in the warm air supply plenum of the original furnace (see Figure 6)

3. removable dampers located in the supply and return plenums of both furnaces permit the isolation of one furnace from the other (see Figure 7)

4. one thermostat is used to control all operating modes. A manual switch located in the basement connects the thermostat to the condensing furnace or to the original furnace.

5. the electric plenum heater is controlled by an outdoor temperature control which is set to signal the back-up furnace to operate at temperatures of $-10^{o}C$ or lower. The outdoor temperature control can be disconnected to allow the plenum heater to operate in colder outdoor temperatures.

6. a manual switch located in the basement is used to disconnect or to reconnect the plenum heater

7. an automatic flue damper installed in the original furnace flue is used to close the chimney when the plenum heater is operating

8. the air distribution system was balanced. A minor modification was made to the distribution system to correct a shortage of return air. An additional cold air return duct, with a return air grille installed in a riser of the stairway leading in the finished basement area, was installed.

The installation was completed by Esso Petroleum Canada. Instrumentation (see Figure 2) and wiring was completed by Eneroil Research Ltd.

The strip chart recorder is a 24-point model from Honeywell. The existing scale was found to be inappropriate for the purposes of this test. Measures are now being taken to change the scale so that chart recordings can be interpreted more easily and accurately.

The condensing oil furnace selected for the test is fired by a Beckett flame retention head burner with a 0.65 USgph nozzle (80^{o} hollow), [ie. equivalent to an input energy rate of 90610 Btuh (26.6 kW)].

The plenum heater is an Esso Econo +2 Model D-9 (9 kW). The automatic flue damper is a Fluegard Model #MFD.

The original furnace is a Waterbury 30, rated at 115,000 Btuh. The existing nozzle size is 0.85 USgph, [ie. equivalent to an input energy rate of 118490 Btuh (34.7 kW)].

It is noteworthy that the condensing oil furnace, with a 0.65 USgph nozzle has a significantly lower input energy rating than the orignal furnace. However, the condensing furnace is still somewhat oversized relative to the design heat load of the test house. A smaller nozzle size may be appropriate in future tests at this site.

5.3 Start-Up Testing and Preliminary Trials

A series of start-up tests were performed on the installed condensing oil furnace on December 9, 1983 and December 12, 1983, prior to the instrumentation of the unit. The test results are:

i)	actual oil flow rate (at steady state):	0.58 USgph
ii)	oil pump pressure:	118 psi
iii)	flue gas analysis: % O_2	6.8
	% CO_2	10.4
iv)	flue gas temperature (vented from unit):	($44^{\circ}C$) $111^{\circ}F$ (gross) ($17^{\circ}C$) $31^{\circ}F$ (net)
v)	flue gas temperature (before condensing process):	($199^{\circ}C$) $390^{\circ}F$ (gross) ($172^{\circ}C$) $310^{\circ}F$ (net)
vi)	steady state efficiency:	94%
vii)	smoke:	0
viii)	overfire draft:	0.03" w.c.
ix)	condensate flow rate:	1.3 litres/hr.
x)	water flow rate (2.5 USgph nozzle):	5.6 litres/hr.

xi) service water temperature: (11°C) 51°F

xii) temperature of condensate and water mixture: (31°C) 88°F

xiii) ph of condensate/water mixture: 3.46

Three operational problems were encountered and remedied during early trials of the condensing oil furnace conducted in January through March, 1984.

1. Moisture was found gathering in an air tube extending from the vent pipe to a pressure switch located in the junction box (see Figure 1). During extended cycles, sufficient moisture would gather to plug the tube and signal a sharp pressure drop to the pressure switch, which would in turn signal the unit to stop. This problem was solved by shortening and straightening the air tube in such a manner as to prevent moisture from gathering. The air tube will be re-routed in future prototypes.

2. The water nozzle (see Item #22 in Figure 1) corroded and clogged prematurely. It was found that the furnace was originally equipped with a steel/nozzle, which was not able to withstand the high degree of acidity of the flue gases. This nozzle was replaced by a brass unit with a stainless steel oriface and a brass filter. This new nozzle, according to the designers, will withstand the high acidity levels.

3. Flue gases were found leaking from around the by-pass valve (see Item #19 in Figure 1). A gasket was installed to correct this problem.

All of the above problems, as noted, were corrected. The information gained from these experiences will be used as input into the continuing process of refining the condensing oil furnace.

Fig. 5
Side-by-Side Installation of Furnaces
(right: Condensing Oil Furnace. left: Original Oil Furnace).

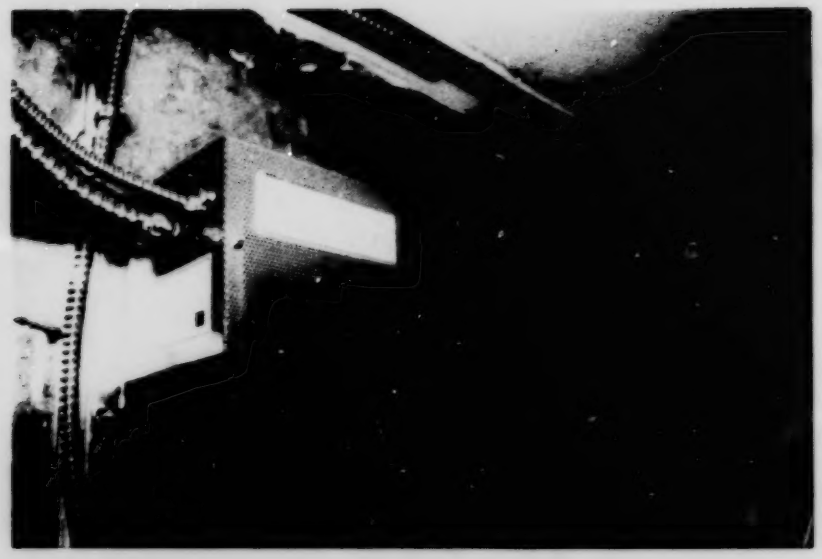


Fig. 6 - Electric Plenum Heater Installed in Warm Air Plenum of Original Oil Furnace.

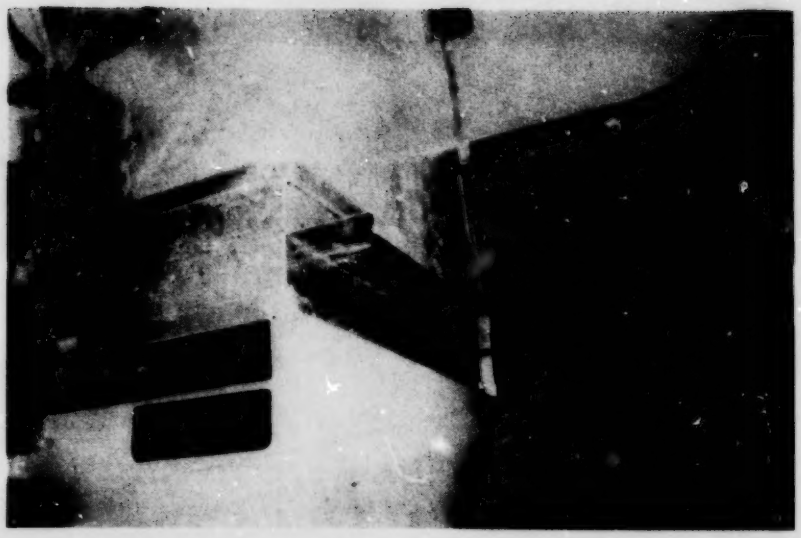


Fig. 7 - Isolation Dampers in Original Oil Furnace

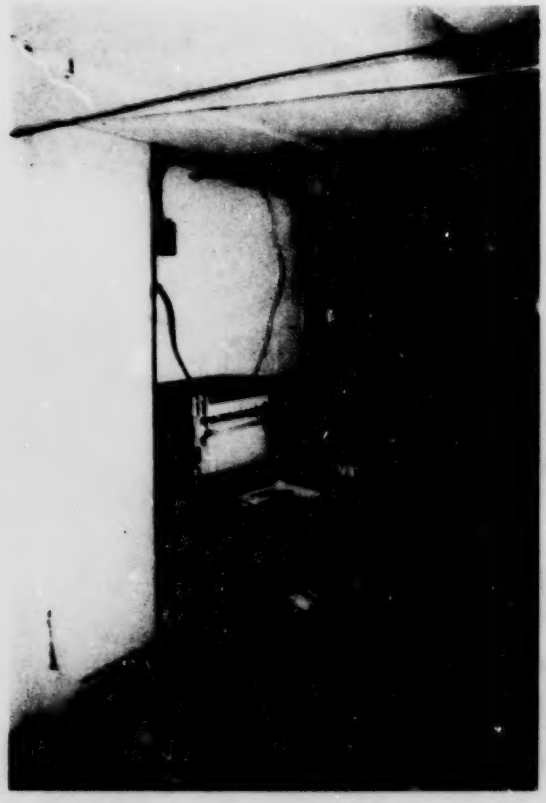


Fig. 8
Strip Chart Recorder

Fig. 9 - Cycle Counters and Elapsed Time Recorder Mounted on Condensing Oil Furnace

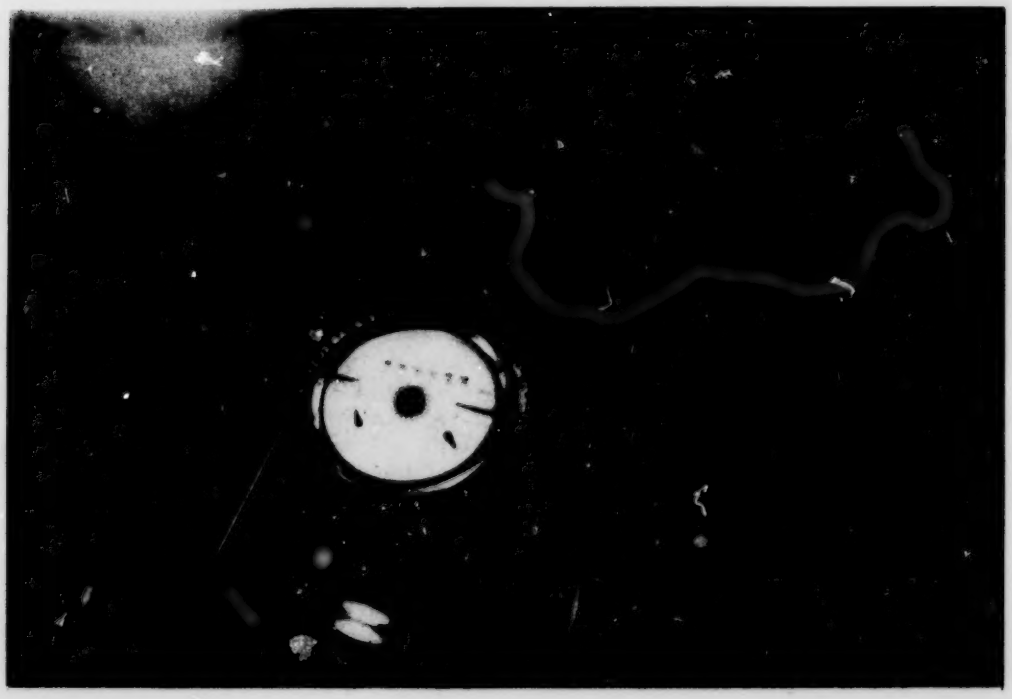


Fig. 10 - Oil Flow Meter

6.0 CONCLUSIONS

The installation of equipment for the purposes of the field test has been completed. The condensing oil furnace has been sucessfully commissioned and is currently operating smoothly and consistently.

Detailed performance results will be presented in a forthcoming "Performance Report".

The condensing oil furnace field test involves participation from both industry and government. Test results will be used to further product development and to contribute to the current body of public information on energy efficient heating equipment.

APPENDIX A

HOTCAN ANALYSIS OF TEST HOUSE

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* * * * * * * * * * * * * * * * * * * * *
*                  HOTCAN!                *
* NATIONAL RESEARCH COUNCIL OF CANADA     *
*    DIVISION OF BUILDING RESEARCH        *
*     SASKATOON, SASKATCHEWAN, 1982       *
*          (RELEASE HOTCAN 4.01)          *
* * * * * * * * * * * * * * * * * * * * *
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CLIENT NAME: TEST HOUSE #1
ADDRESS : TORONTO

USER DATA FILE NAME: OTEST,1

DATA IS FOR TORONTO

***** BUILDING PARAMETERS *****

ELEMENTS	HOUSE VOLUME	AIR CHANGE	HT LOSS W/DEGC	% SEASONAL HT LOSS
VENTILATION	498.76 M3	.3/HR	46.15	10.33
	AREA M2	RSI VALUE M2-DEGC/W		
CEILING	111.50	3.74		
	18.60	3.92		
TOTAL	130.10	3.76	34.56	7.73
MAIN WALLS	118.50	1.32		
	22.30	.85		
	27.40	.75		
TOTAL	168.20	1.10	152.54	34.14
DOORS	3.30	.24		
TOTAL	3.30	.24	13.75	3.08
BASEMENT AB.GD	22.30	.38		
TOTAL	22.30	.38	58.68	13.13
BASEMENT 600MM	18.60	.00		
TOTAL	18.60	.00	35.34	6.01
BASE. TO FLOOR	18.60	.00		
TOTAL	18.60	.00	16.72	2.84
FLOOR PERIMETER	27.90	.00		
TOTAL	27.90	.00	14.21	2.42
FLOOR CENTRE	27.90	.00		
TOTAL	27.90	.00	5.44	.92
SOUTH WINDOWS	.00	.00		
TOTAL	.00	.00	.00	.00
NORTH WINDOWS	.00	.00		
TOTAL	.00	.00	.00	.00
EAST WINDOWS	14.30	.30		
TOTAL	14.30	.30	47.67	10.67

WEST WINDOWS	11.70	.30		
TOTAL	11.70	.30	39.00	8.73
S-EAST WINDOWS	.00	.00		
TOTAL	.00	.00	.00	.00
S-WEST WINDOWS	.00	.00		
TOTAL	.00	.00	.00	.00

ADDRESS : TORONTO

DESIGN HEAT LOSS AT -17.2C = 16.15 KW
DEGREE DAYS FOR TORONTO IS 4082
TEMPERATURES (DEG C) MAIN FLOOR = 20 BASEMENT = 17
SENSIBLE HEAT GAIN FROM PEOPLE (KWH/D) = 3.2
DAILY BASE ELECTRIC CONSUMPTION (KWH/D) = 14
DAILY HOT WATER ENERGY CONSUMPTION (KWH/D) = 14
MASS LEVEL CHOSEN IS (A)
BASEMENT INSULATED PRIMARILY FROM THE INSIDE
WINDOW SHADING COEFFICIENTS: SOUTH = 0 NORTH = 0
EAST = .89 WEST = .89
S-EAST = 0 S-WEST = 0
SOUTH OVERHANG GEOMETRY: AVERAGE WINDOW HEIGHT = 0
AVERAGE OVERHANG WIDTH = 0
AVERAGE HEIGHT ABOVE WINDOW = 0
NATURAL INFILTRATION RATE (AC/HR) = .3
FORCED VENTILATION RATE (AC/HR) = 0

***** MONTHLY SUMMARY OF ENERGY CONSUMPTION *****

MONTH	THERMAL LOAD KWH/D	MONTHLY SOLAR FRAC	AUX HEAT REQ KWH/D	TOT CONS KWH/D
JAN	254.94	.09	232.21	260.21
FEB	249.90	.14	215.60	243.60
MAR	200.39	.21	158.17	186.17
APR	126.14	.32	85.98	113.98
MAY	65.37	.46	35.31	63.31
JUN	3.71	1.00	.00	28.00
JUL	.00	1.00	.00	28.00
AUG	.00	1.00	.00	28.00
SEP	28.17	.81	5.49	33.49
OCT	89.23	.30	62.22	90.22
NOV	155.65	.11	138.35	166.35
DEC	225.79	.07	209.50	237.50

***** YEARLY ENERGY CONSUMPTION COMPARISONS *****

12 MONTH HEATING SEASON IN EFFECT
ANNUAL SOLAR HEATING CONTRIBUTION = 18 %

ESTIMATED ANNUAL SPACE HEATING 124 GJ, OR 34,551 KWHRS
SEEH PROGRAM ENERGY BUDGET FOR SPACE HEATING = 7,105 KWHRS

PREDICTED ANNUAL AUXILIARY ENERGY CONSUMPTION = 10,220 KWHRS
SEEH PROGRAM AUXILIARY ENERGY CONSUMPTION = 10,600 KWHRS

TOTAL ANNUAL ENERGY CONSUMPTION = **44,771 KWHRS**
TOTAL ANNUAL SEEH PROGRAM ENERGY BUDGET = **17,705 KWHRS**

***** ANNUAL PREDICTED FUEL COSTS *****

FUEL COSTS ARE FOR ONTARIO AS OF 84/01/27

ENERGY SOURCE	COST PER UNIT	SPACE HEATING	HOT WATER	LIGHTS AND APPLIANCES
OIL	33.3C/LITRE	$ 1517.27/YR EFF.= 70%	--	--

****

This estimate of energy demand may not reflect actual energy requirements of a house due to variations in weather, performance of equipment, and the lifestyle of the occupants.

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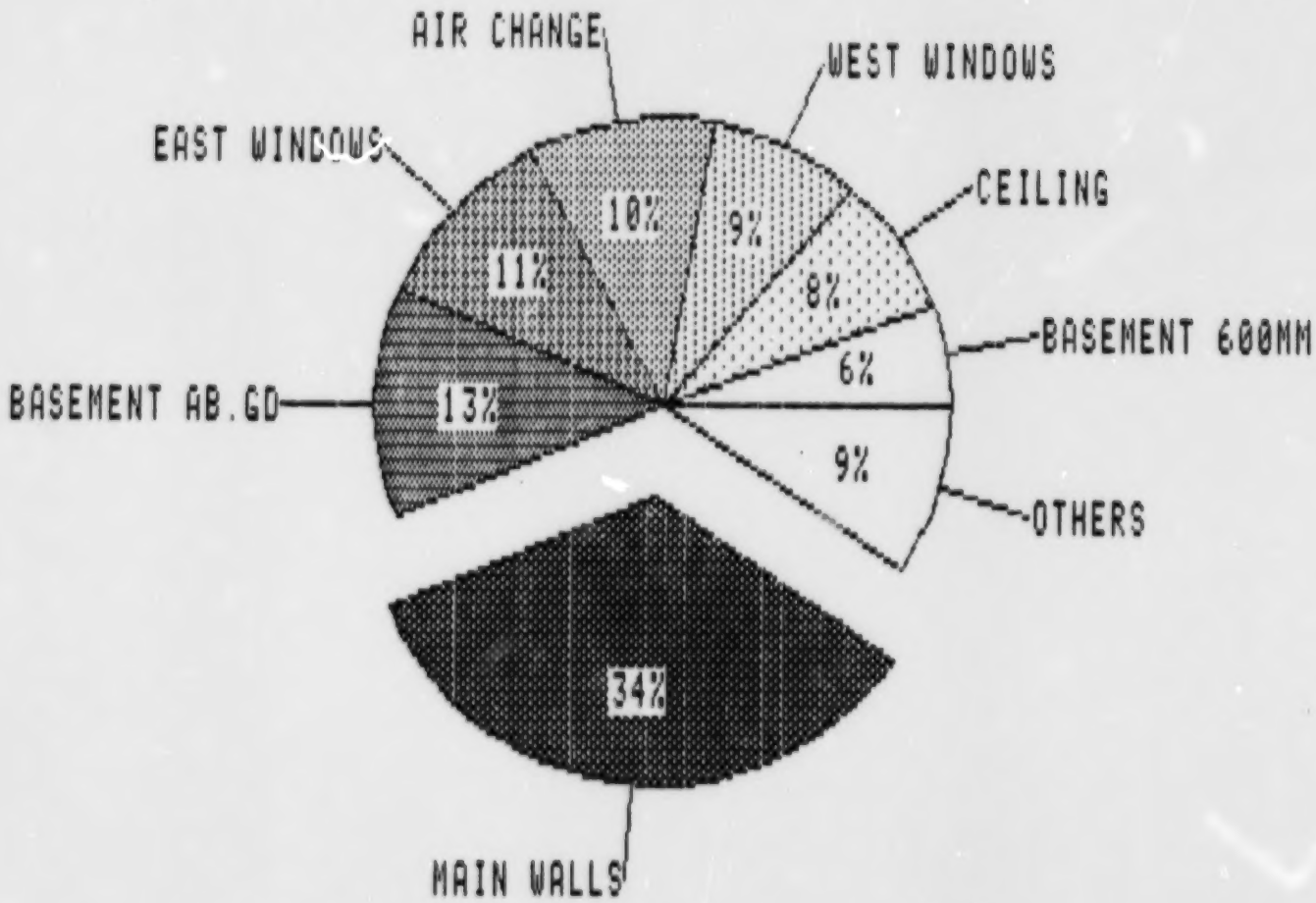
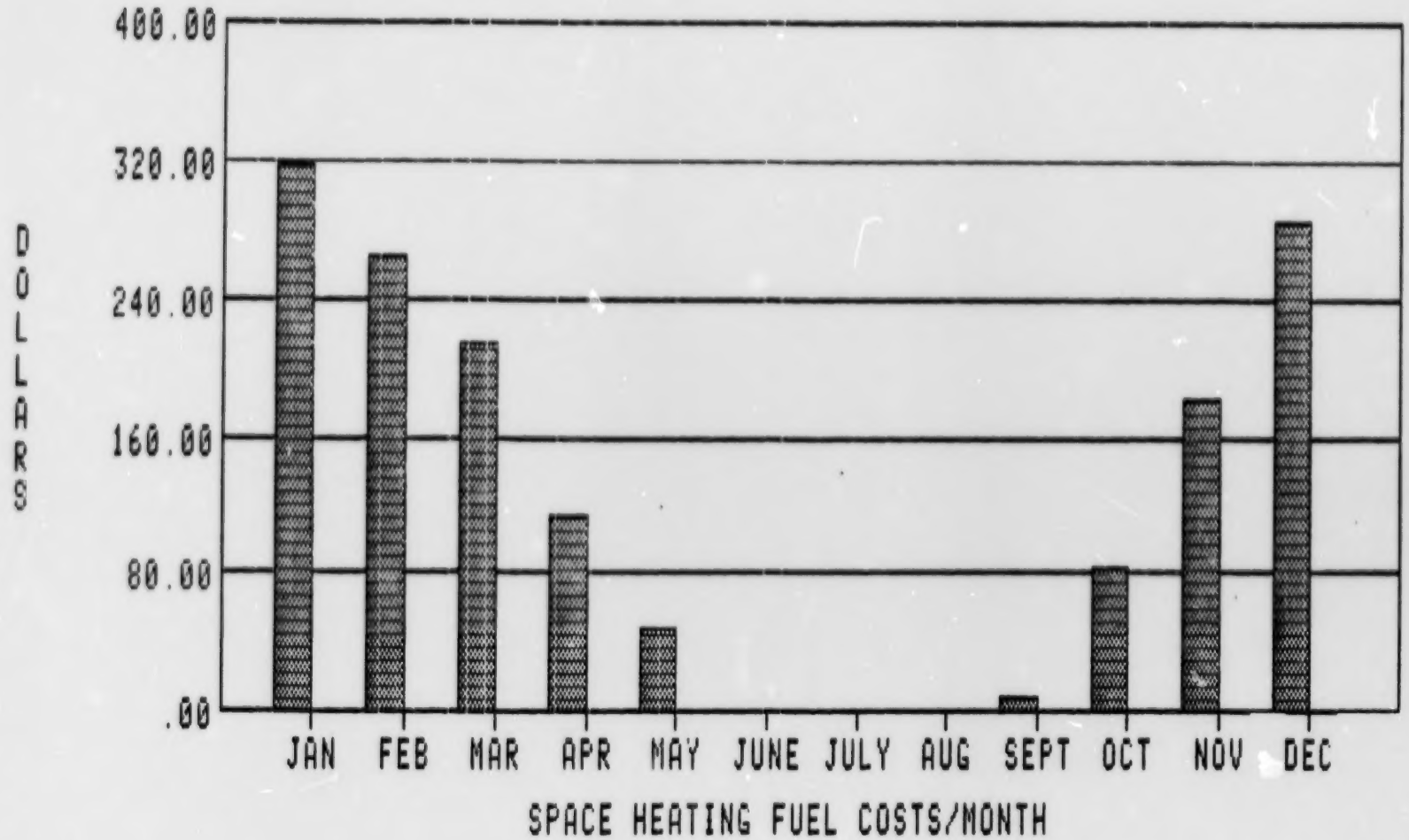
COMPONENT ENERGY LOSS CHART FOR OTEST



ENERGY LOSSES LESS THAN 4% ARE NOT REPRESENTED
PASSIVE SOLAR ENERGY GAINS FROM WINDOWS ARE NOT REPRESENTED



OTEST HOUSE OIL HEATING - 70% EFF - YRLY SPACE HEATING = $ 1517

POOR

QUALITY

ORIGINAL